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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
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If no title is shown please refer to the description.
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Electrowetting lenses with large optical power

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Electrowetting lenses with large optical power

Introduction

In electrowetting-based lenses the optical power of the lens depends on the curvature of the meniscus and the difference in refractive indices between the conductive and non-conductive liquids, as can be seen in equation (1):

$$S = \frac{n_1 - n_2}{r}$$

Equation (1), with S the optical power of the meniscus, r the radius of curvature of the meniscus, n_1 the refractive index of the non-conductive liquid and n_2 the refractive index of the conductive liquid

From equation (1) follows that by increasing the refractive index of the non-conductive liquid, the optical power of the electrowetting lens can be increased (see figure 1).

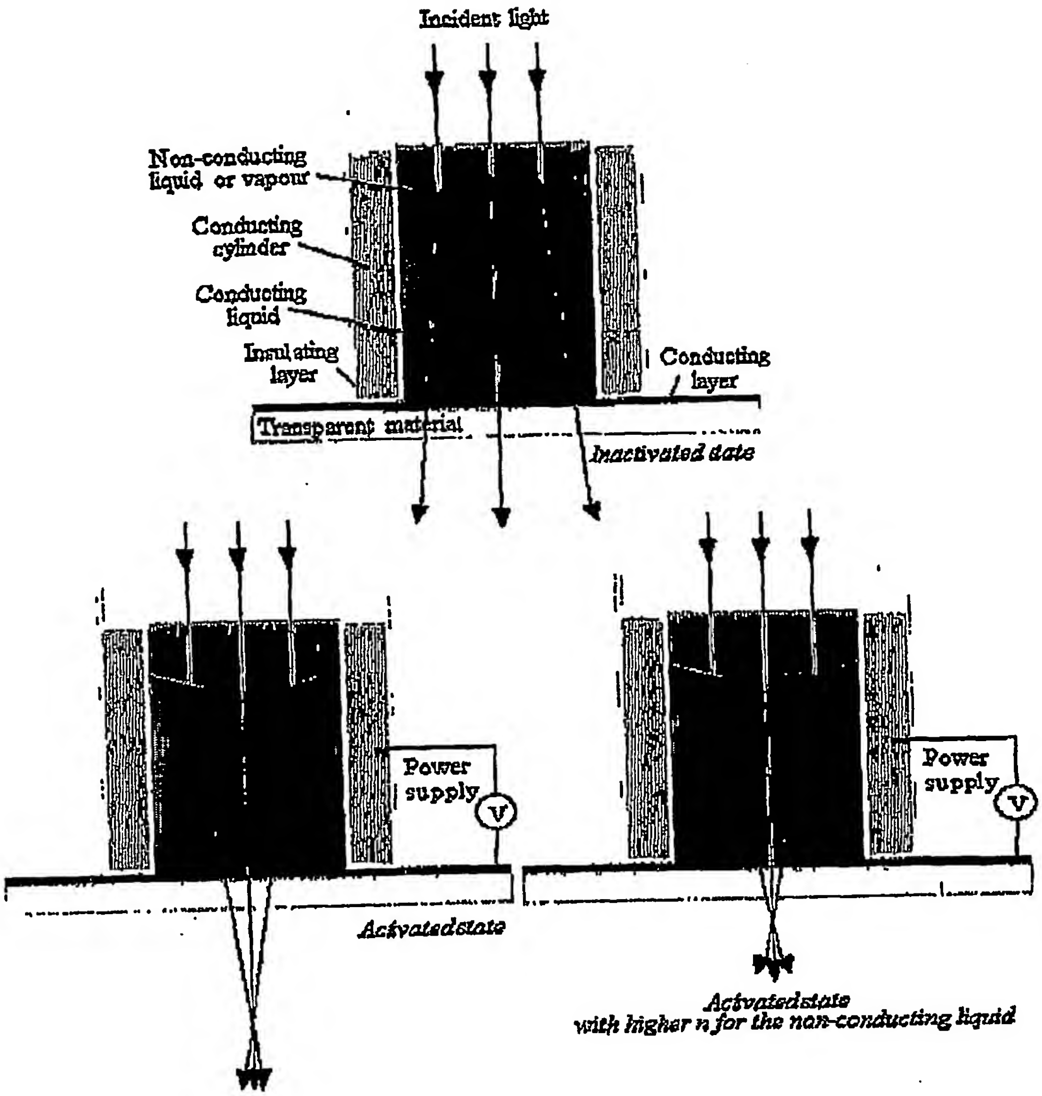

Figure 1: Schematic representation of an electrowetting based lens

The optical power change depends on the difference in refractive indices between the conducting and non-conductive liquids and on the change in curvature of the meniscus. For a zoom lens based on electrowetting the maximum attainable zoom factor is strongly related to the change in optical power of the electrowetting lenses. Therefore, electrowetting lenses that can produce large optical power variations are required. Since the maximum change in curvature is determined by the size of the electrowetting cell, the change in optical power caused by change in curvature is limited for an electrowetting lens. A larger optical power change can be achieved by enlarging the difference in refractive index between the conductive liquid and the non-conductive liquid. The non-conductive liquids usually applied in electrowetting lenses (e.g. alkanes or silicone oils) have only a slightly larger refractive index (n=1.37-1.43) than the usually applied conductive liquids (e.g. water, n=1.33). Typically the difference in refractive index is below 0.1. There are lenses described in literature with a larger difference, such as water and chloro-naphtalene, but these lenses do not show good electrowetting behaviour, especially for DC voltages.
Another advantage of liquids with a large difference in refractive index is that the required curvature for a certain optical power can be made lower, thus reducing the sensitivity for optical aberration in the optical system. Moreover, the required actuation voltage to achieve a certain change in optical power is lower.

Technical problem

The problem is thus to find non-conducting liquids with high refractive indices suitable for electrowetting lenses. This requires that these liquids are transparent, non-miscible with the conductive liquid, have a density substantially similar to that of the conductive liquid, have proper melting and boiling points and show a good electrowetting behaviour.

Solution

We propose to use non-conducting liquids or solutions that contain phenyl groups, as the non-polar liquid in an electrowetting based lens. The phenyl groups cause high refractive indices in the liquids or solutions and have the desired properties for electrowetting lenses (such as high transparency, non-miscibility with water, and good electrowetting behaviour). Some examples of non-conducting liquids or soluble solids containing phenyl groups are given in table 1:

Material	State	Refractive index
1,1,5,5-tetraphenyl–1,3,3,5-tetramethyltrisiloxane	Liquid	1.551
1,3,3,5-tetraphenyldimethyldisiloxane	Solid	1.5866
3,5,7-triphenylnonamethylpentasiloxane	liquid	1.501
triphenyltrimethylcyclotrisiloxane	liquid	1.5402
1,1,3,5,5-pentaphenyl-1,3,5-trimethyltrisiloxane	liquid	1.5797
phenyltrimethylsilane	liquid	1.4908
toluene	Liquid	1.496
diphenylmethane	Solid T_m=22°C	1.577
biphenyl	Solid	1.588

Table 1: Materials containing phenyl groups

From table 1 it follows that these liquids with phenyl groups have refractive indices typically larger than 1.49, making them suitable for electrowetting lenses with large optical power range. Preferably, the subset with a refractive index greater than 1.5 is particularly suited because they allow miniaturised zoom lenses for portable applications (for instance mobile phone) with zoom factor greater than two. Even more preferred are these liquids with phenyl groups with refractive index n>1.55, for instance 1,1,5,5-tetraphenyl–1,3,3,5-tetramethyltrisiloxane.
Preferably, the non-conducting liquid is a silicone oil, i.e. a siloxane, having phenyl groups. Such an oil remains long in the liquid state on adding more phenyl groups.

Application

Non-conducting liquids that contain phenyl groups may be used in any electrowetting element, in particular electrowetting variable-focus lenses and zoom lenses, diaphragms, gratings, filters and beam deflectors. Examples of such devices have been disclosed in international patent application no. IB03/00222 (PH-NL020163), European patent applications no. 02078939.2 (PH-NL020947), no. 02080387.0 (PH-NL021251) and no. 02080060.3 (PH-NL021187). These electrowetting elements can be used in devices such as optical scanning devices, cameras, mini-cameras in mobile phones, displays, etc.

Claims:

1 An optical element comprising a fluid chamber including a first body of a first fluid and a second body of a second fluid, the two bodies being separated by a meniscus, the position and/or shape of which is electrically controllable, the first fluid being electrically conducting and the second fluid being electrically non-conducting, characterized in that the second fluid essentially comprises molecules having a phenyl group.

2 An optical element as claimed in Claim 1, wherein the second fluid is a silicon oil having a phenyl group.

3 An optical element as claimed in Claim 1, in which the molecules having a phenyl group do not comprise phenyl methyl siloxane.

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